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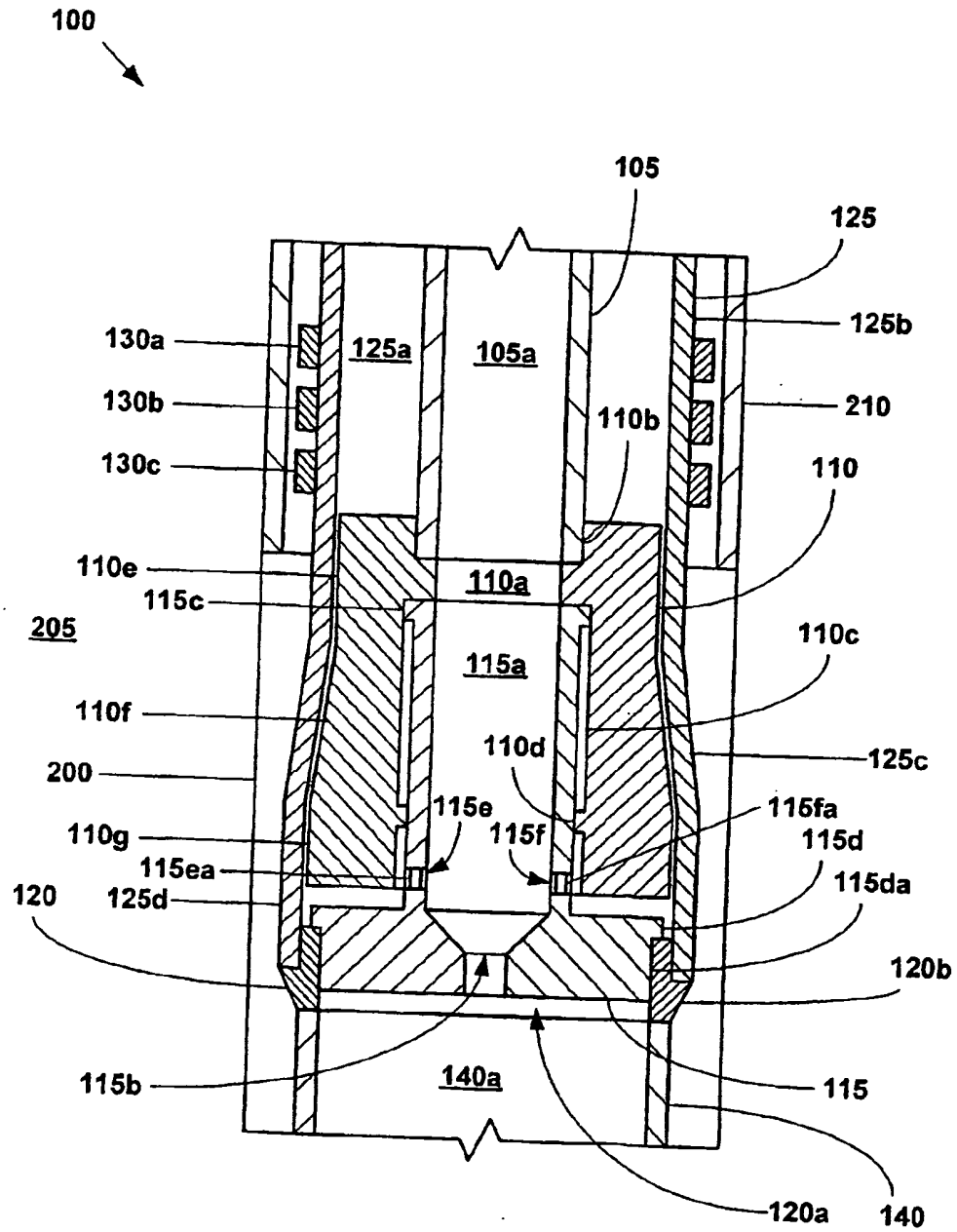
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**Fig. 1**

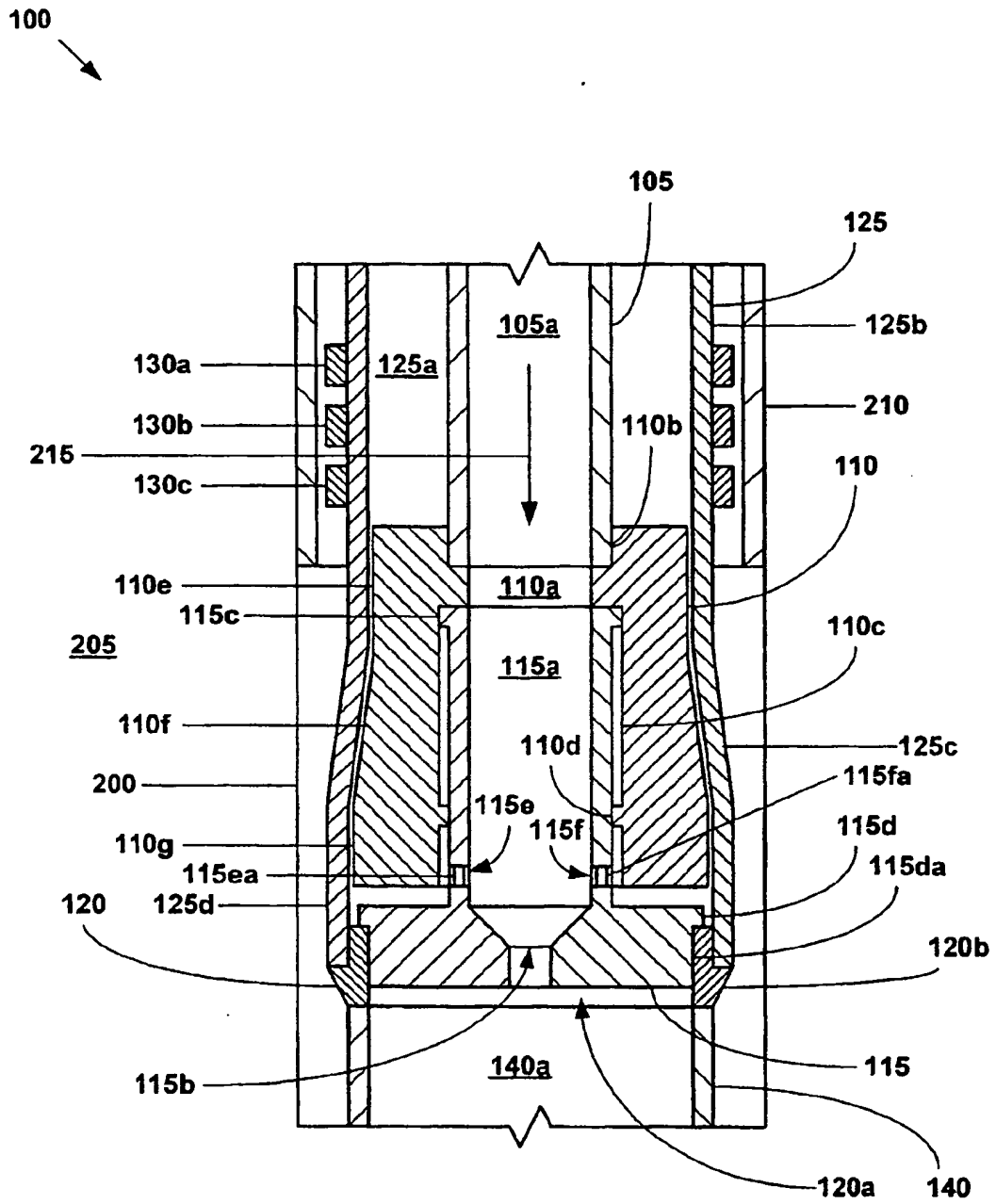


Fig. 2

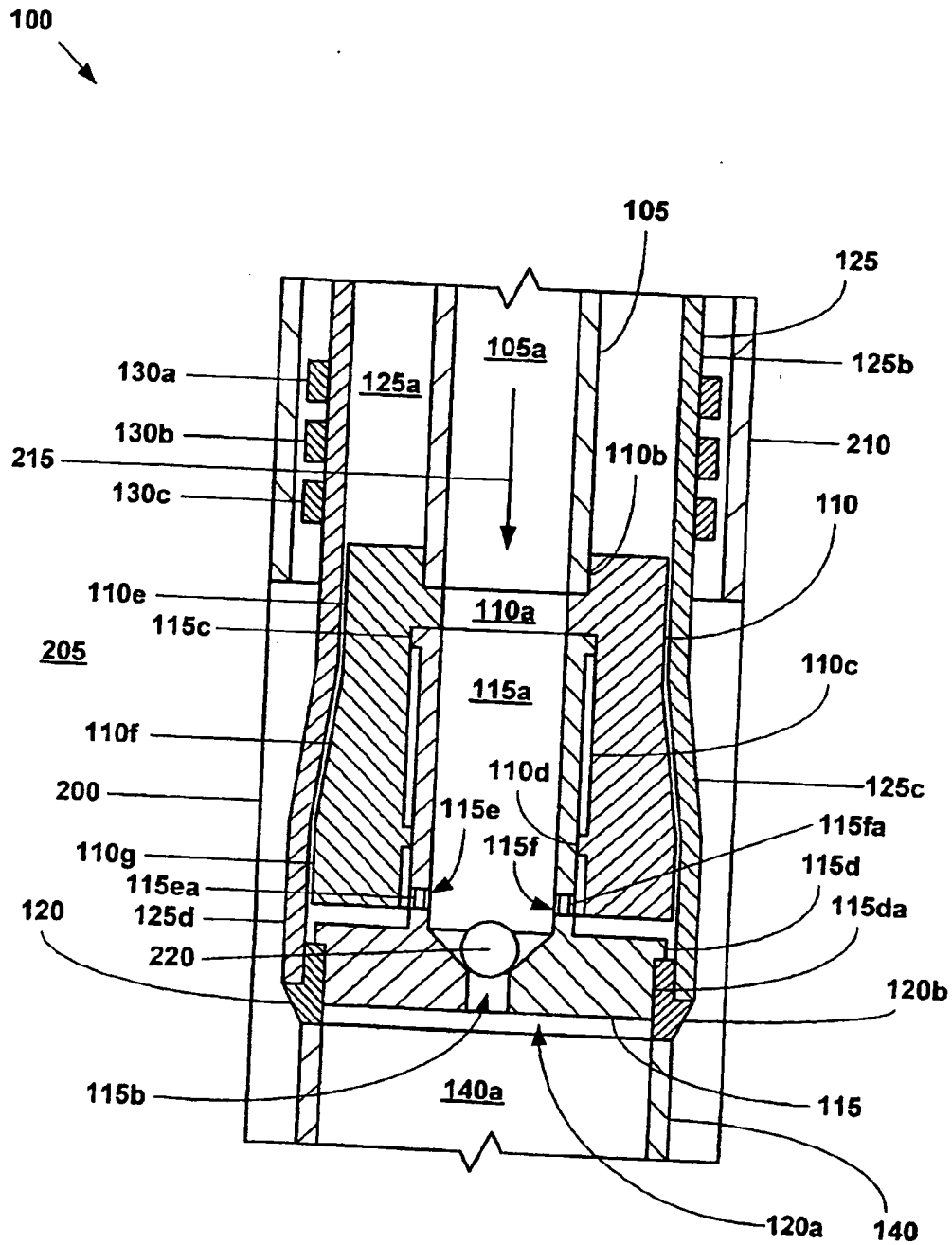


Fig. 3

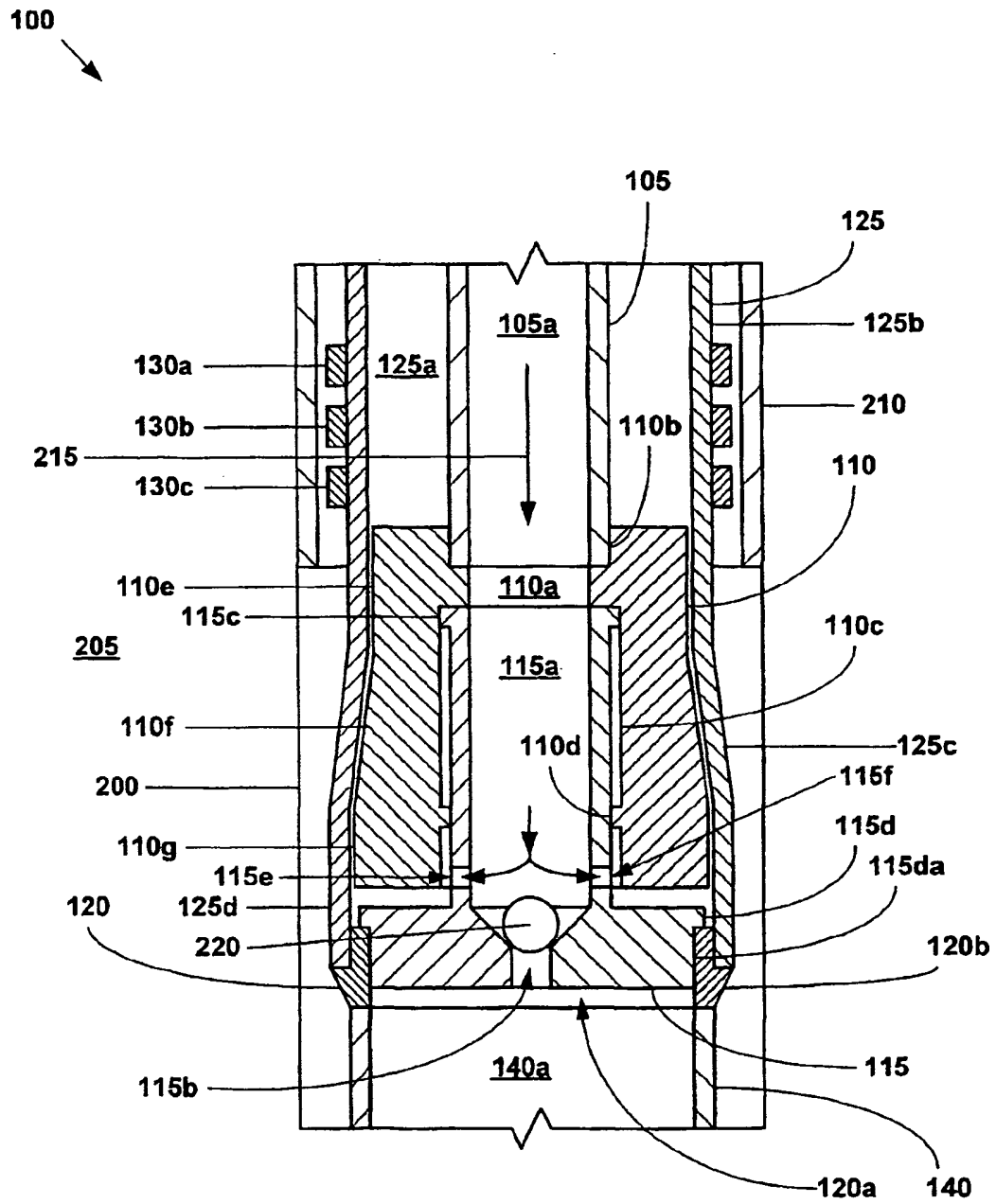


Fig. 4

100

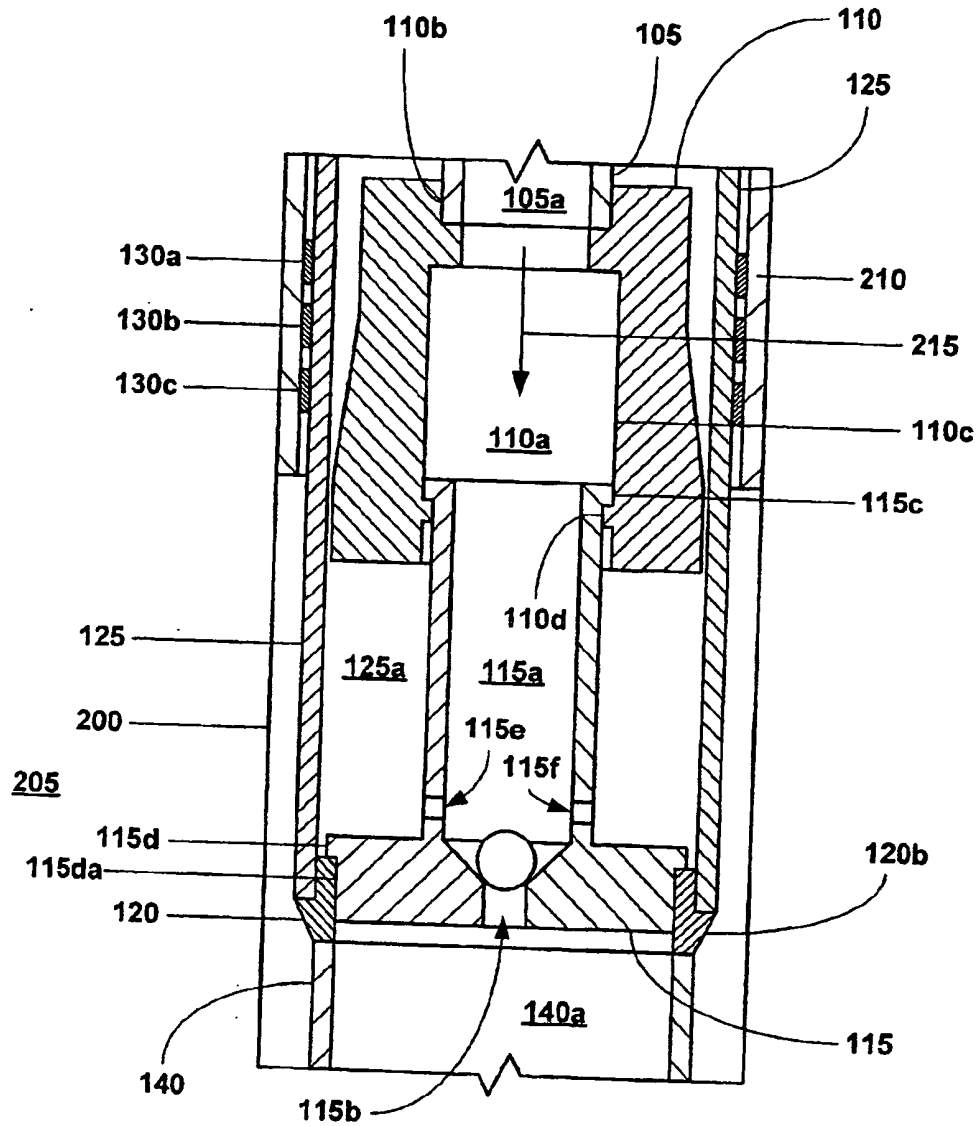


Fig. 5

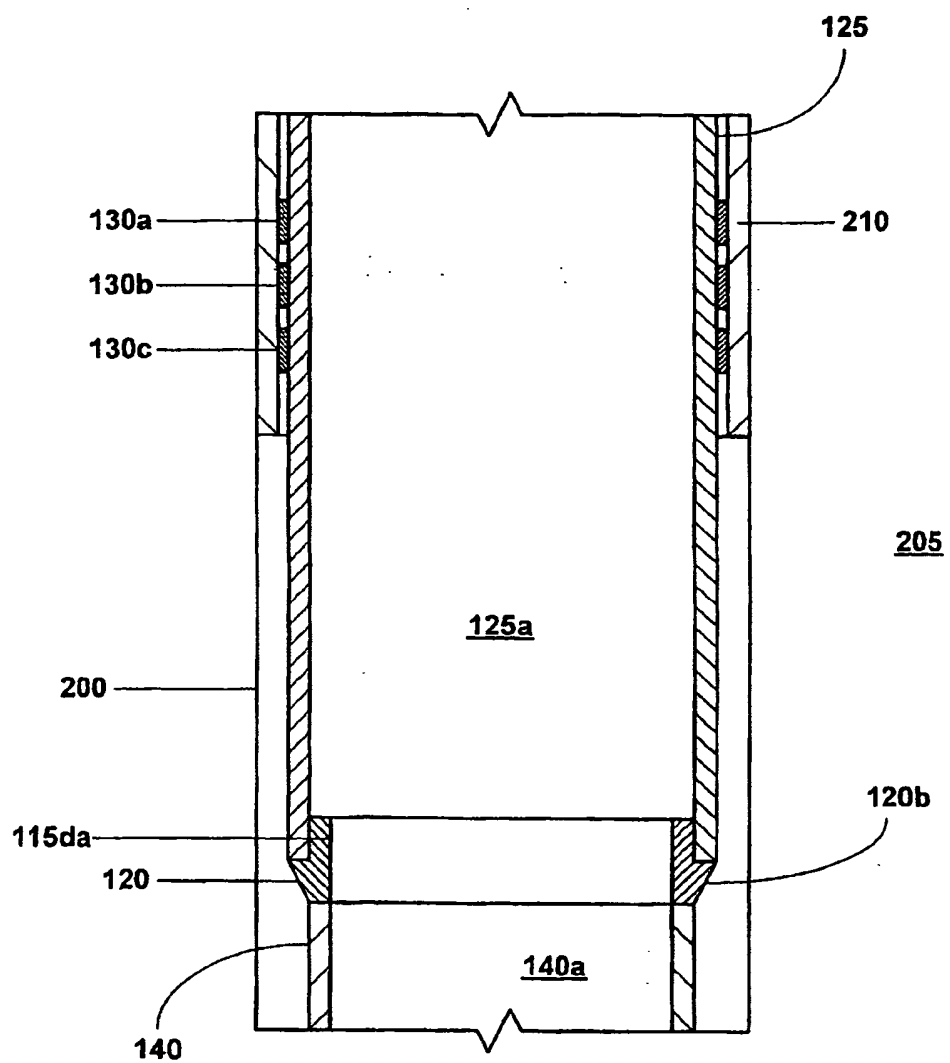
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Fig. 6

## LINER HANGER

This invention relates generally to wellbore casings, and in particular to wellbore casings that are formed using expandable tubing.

5

## Background of the Invention

Conventionally, when a wellbore is created, a number of casings are installed in the borehole to prevent collapse of the borehole wall and to prevent undesired outflow of drilling fluid into the formation or inflow of fluid from the formation into the borehole. The borehole is drilled in intervals whereby a casing which is to be installed in a lower borehole interval is lowered through a previously installed casing of an upper borehole interval. As a consequence of this procedure the casing of the lower interval is of smaller diameter than the casing of the upper interval. Thus, the casings are in a nested arrangement with casing diameters decreasing in downward direction. Cement annuli are provided between the outer surfaces of the casings and the borehole wall to seal the casings from the borehole wall. As a consequence of this nested arrangement a relatively large borehole diameter is required at the upper part of the wellbore. Such a large borehole diameter involves increased costs due to heavy casing handling equipment, large drill bits and increased volumes of drilling fluid and drill cuttings. Moreover, increased drilling rig time is involved due to required cement pumping, cement hardening, required equipment changes due to large variations in hole diameters drilled in the course of the well, and the large volume of cuttings drilled and removed.

The present invention is directed to overcoming one or more of the limitations of the existing procedures for forming wellbores and wellheads.

25

## Summary of the Invention

According to a first aspect of the present invention there is provided a method of coupling a radially expandable tubular member to a preexisting structure, comprising:

- positioning the tubular member within the preexisting structure;
- injecting fluidic materials into the tubular member;
- sensing the operating pressure of the fluidic materials;
- radially expanding and plastically deforming the tubular member into contact with the preexisting structure when the sensed operating pressure exceeds a predetermined amount; and

radially expanding and plastically deforming the tubular member using an expansion device when the sensed operating pressure exceeds the predetermined amount.

Preferably, the expansion device comprises a tubular expansion cone.

5 Preferably, sensing the operating pressure includes:

sensing the operating pressure of the fluidic materials within the tubular member.

Preferably, radially expanding and plastically deforming the tubular member using the expansion device when the sensed operating pressure exceeds the predetermined amount comprises:

10 radially expanding and plastically deforming the tubular member by displacing the expansion device in the longitudinal direction relative to the tubular member when the sensed operating pressure exceeds the predetermined amount.

Preferably, the method further comprises movably coupling a tubular shoe to the expansion device.

15 Preferably, the method further comprises removing the tubular shoe from the preexisting structure.

Preferably, the method further comprises removing the tubular shoe from the preexisting structure by lifting the tubular shoe using the tubular expansion cone.

20 Preferably, the method further comprises coupling a shoe to an end of the tubular member;

positioning the expansion device within the tubular member; and  
removing the shoe from the interior of the tubular member using the expansion device;

25 wherein radially expanding and plastically deforming the tubular member using the expansion device when the sensed operating pressure exceeds the predetermined amount comprises:

pressurizing an interior portion of the tubular member defined between the shoe and the expansion device to radially expand and plastically deform the tubular member.

30 Preferably, the method further comprises coupling a shoe to an end of the tubular member;

positioning an expansion device within the tubular member; and  
removing the shoe from the interior of the tubular member using the expansion device.

Preferably, the method further comprises removing the shoe from the interior of the tubular member by lifting the shoe using the expansion device.

Preferably, the tubular member comprises a wellbore casing, a pipeline, or a structural support.

5 According to a second aspect of the present invention there is provided a system for coupling a radially expandable tubular member to a preexisting structure, comprising:

means for positioning the tubular member within the preexisting structure;

means for injecting fluidic materials into the tubular member;

means for sensing the operating pressure of the fluidic materials;

10 means for radially expanding the tubular member into contact with the preexisting structure when the sensed operating pressure exceeds a predetermined amount; and

means for radially expanding and plastically deforming the tubular member using an expansion device when the sensed operating pressure exceeds the predetermined amount.

15 Preferably, the system further comprises a tubular support member including a first passage;

wherein the expansion device comprises:

20 a tubular expansion cone coupled to the tubular support member defining a second passage and including an internal flange;

wherein the means for radially expanding and plastically deforming the tubular member using an expansion device when the sensed operating pressure exceeds the predetermined amount comprises:

25 a tubular shoe movably received within the second passage of the tubular expansion cone defining one or more radial passages and a valveable passage fluidically coupled to the first passage and including an external flange for engaging the internal flange; and

one or more pressure relief valves positioned in corresponding ones of the radial passages; and

30 wherein an expandable tubular member is movably coupled to the tubular expansion cone.

Preferably, the expansion device comprises a tubular expansion cone.

Preferably, the means for sensing the operating pressure includes:

means for sensing the operating pressure of the fluidic materials within the tubular member.

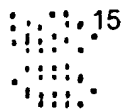
Preferably, the means for radially expanding and plastically deforming the tubular member using an expansion device when the sensed operating pressure exceeds the predetermined amount comprises:

- 5 means for radially expanding and plastically deforming the tubular member by displacing the expansion device in the longitudinal direction relative to the tubular member when the sensed operating pressure exceeds the predetermined amount.

Preferably, the system further comprises a support member to which the expansion device is movably coupled

- 10 wherein the expansion device comprises:  
one or more expansion surfaces adapted to be displaced in the longitudinal direction relative to the support member for engaging and radially expanding and plastically deforming the expandable tubular member;

wherein the means for radially expanding and plastically deforming the tubular member using the expansion device when the sensed operating pressure exceeds the predetermined amount comprises:



- 15 one or more pressure sensing elements coupled to the expansion surfaces; and  
wherein the one or more pressure sensing elements control the longitudinal displacement of



- 20 the expansion surfaces as a function of the sensed operating pressure within the expandable tubular member.



- 25 Preferably, the system further comprises means for movably coupling a tubular shoe to the expansion device.

- Preferably, the system further comprises  
an end of a tapered tubular member coupled to an end of the expandable tubular member;

an end of another tubular member coupled to another end of the tapered tubular member;

- 25 a tubular support member;

- wherein the expansion device comprises a tubular expansion cone;

- 30 wherein an end of the tubular expansion cone is coupled to an end of the tubular support member and positioned within the tapered tubular member, wherein another end of the tubular expansion cone comprises an internal flange; and

wherein the means for radially expanding and plastically deforming the tubular member using the expansion device when the sensed operating pressure exceeds the predetermined amount comprises:

an end of a tubular shoe defining a valveable longitudinal passage and one or  
5 more radial passages supported by the end of the other tubular member, wherein  
another end of the tubular shoe comprises an external flange; and  
one or more burst discs coupled to and positioned within each of the radial  
passages.

10 Preferably, the system further comprises means for coupling a shoe to an end of  
the tubular member;

means for positioning the expansion device within the tubular member; and  
means for removing the shoe from the interior of the tubular member using the  
expansion device;

15 wherein the means for radially expanding and plastically deforming the tubular  
member using the expansion device when the sensed operating pressure exceeds the  
predetermined amount comprises:

20 means for pressurizing an interior portion of the tubular member defined between  
the shoe and the expansion device to radially expand and plastically deform the tubular  
member.

25 Preferably, the system further comprises:

means for coupling a shoe to an end of the tubular member;  
means for positioning the expansion device within the tubular member;  
and

30 means for removing the shoe from the interior of the tubular member using the  
expansion device.

Preferably, the system further comprises means for removing the shoe from the  
interior of the tubular member by lifting the shoe using the expansion device.

Preferably, the tubular member comprises a wellbore casing, a pipeline, or a  
structural support.

#### Brief Description of the Drawings

Fig. 1 is a fragmentary cross-sectional illustration of an embodiment of a liner  
hanger positioned within a wellbore including a preexisting section of wellbore casing.

Fig. 2 is a fragmentary cross-sectional illustration of the injection of a fluidic material into the apparatus of Fig. 2.

Fig. 3 is a fragmentary cross-sectional illustration of the placement of a ball into the valveable passage of the tubular shoe of the apparatus of Fig. 2.

5 Fig. 4 is a fragmentary cross-sectional illustration of the continued injection of the fluidic material into the apparatus of Fig. 3 in order to burst the burst discs.

Fig. 5 is a fragmentary cross-sectional illustration of the continued injection of the fluidic material into the apparatus of Fig. 4 in order to plastically deform and radially expand the expandable tubular member.

10 Fig. 6 is a fragmentary cross-sectional illustration of the completion of the radial expansion and plastic deformation of the expandable tubular member of the apparatus of Fig. 5.

#### Detailed Description of the Illustrative Embodiments

15 An apparatus and method for plastically deforming a tubular liner within a wellbore within a subterranean formation is provided. The apparatus and method thereby provides a system for coupling a radially expandable tubular liner to an open hole or cased section of a wellbore within a subterranean formation. Furthermore, in this manner, a wellbore casing, a pipeline, or a structural support may be formed or repaired using the present illustrative embodiments.

20 Referring initially to Fig. 1, an embodiment of an apparatus 100 for radially expanding and plastically deforming a tubular liner includes a tubular support member 105 that defines a passage 105a that is coupled to a tubular expansion cone 110 that defines a passage 110a and includes a recess 110b for mating with and receiving the tubular support member 105, a recess 110c, and an internal flange 110d. The tubular expansion cone 110 further includes a first section 110e having a substantially cylindrical outer surface, a second section 110f having a substantially tapered conical outer surface, and a third section 110g having a substantially cylindrical outer surface. In an exemplary embodiment, the outside diameter of the first section 110e is greater than the outside diameter of the third section 110g. In an exemplary embodiment, the recess 110b includes internal threads and the end of the tubular support member 105 that is received within the recess 110b includes external threads for engaging the internal threads.

25 An end of a tubular shoe 115 mates with and is movably received within the recess 110c of the tubular expansion cone 110 that defines a passage 115a and a

valveable passage 115b and includes an external flange 115c, and an external flange 115d including a recessed portion 115da. The tubular shoe 115 further includes radial passages 115e and 115f for receiving corresponding burst discs, 115ea and 115fa. An end of a tubular support member 120 that defines a passage 120a mates with and is  
5 movably received within the recess 115da of the external flange 115d of the tubular shoe 115 and includes an external flange 120b having a substantially conical outer surface.

An end of an expandable tubular member 125 mates with and is coupled to the tubular support member 120 that defines a passage 125a for receiving the tubular  
10 support member 105, the tubular expansion cone 110, and the tubular shoe 115. In an exemplary embodiment, the end of the expandable tubular member 125 is coupled to the tubular support member 120 by a conventional threaded connection. In an exemplary embodiment, the expandable tubular member 125 includes a first section 125b having a substantially cylindrical outer surface, a second section 125c having a  
15 substantially conical outer surface, and a third section 125d having a substantially cylindrical outer surface. In an exemplary embodiment, the outside diameter of the first section 125b is greater than the outside diameter of the third section 125d. a plurality of tubular sealing members, 130a, 130b, and 130c, are coupled to the external surface of the first section 125b of the expandable tubular member 125.

20 An end of a tubular member 140 that defines a passage 140a is coupled to an end of the tubular support member 120. In an exemplary embodiment, the connection between the tubular member 140 and the tubular support member 120 is a conventional threaded connection.

In an exemplary embodiment, as illustrated in Fig. 1, the apparatus 100 may be  
25 positioned within a wellbore 200 within a subterranean formation 205 that includes a preexisting section of wellbore casing 210. The wellbore 200 may be vertical, horizontal, or an intermediate orientation.

As illustrated in Fig. 2, a fluidic material 215 may then be injected into the apparatus 100 through the passages 105a, 110a, 115a, 115b, and 140a in order to  
30 ensure the proper operation of the passages. In an alternative embodiment, before or after the injection of the fluidic material 215, a hardenable fluidic sealing material such as, for example, cement, may be injected into the apparatus 100, through the passages 105a, 110a, 115a, 115b, and 140a, in order to form an annular body of a fluidic sealing material between the tubular member 125 and the wellbore 200.

As illustrated in Fig. 3, a ball 220 may then be placed into the valveable passage 115b of the tubular shoe 115 by introducing the ball into the injected fluidic material 215. In this manner, the valveable passage 115b of the tubular shoe 115 may be sealed off thereby permitting the passage 115a to be pressurized by the continued injection of the fluidic material 215.

As illustrated in Fig. 4, the continued injection of the fluidic material 215 will burst the burst discs 115ea and 115fa thereby permitting the injected fluidic material to pass through the radial passages 115e and 115f into the annular region between the tubular shoe 115 and the expandable tubular member 125 below the tubular expansion cone 110 above the external flange 115d of the tubular shoe.

As illustrated in Fig. 5, the continued injection of the fluidic material 215 will continue to pressurize the annular region, between the tubular shoe 115 and the expandable tubular member 125 below the tubular expansion cone 110 above the external flange 115d of the tubular shoe, and thereby extrude the expandable tubular member 125 off of the tubular expansion cone 110 by plastically deforming and radially expanding the expandable tubular member.

During the continued radial expansion of the expandable tubular member 125, the tubular support member 105 and the tubular expansion cone 110 may be raised out of the wellbore 200. Because the tubular expansion cone 110 and the tubular shoe 115 are movably coupled, the axial displacement of the tubular expansion cone 110 during the radial expansion of the tubular member 125 does not displace the tubular shoe in the axial direction. In an exemplary embodiment, during the radial expansion and plastic deformation of the expandable tubular member 125, the tubular shoe 120 is supported by the tubular support member 120 in the axial direction.

In an exemplary embodiment, the radial expansion of the expandable tubular member 125 further causes the sealing members, 130a, 130b, and 130c, to engage the preexisting wellbore casing 210. In this manner, the radially expanded tubular member 125, the tubular support member 120, and the tubular member 140 are coupled to the preexisting wellbore casing. Furthermore, in this manner, a fluidic seal is provided between the radially expanded tubular member 125 and the preexisting wellbore casing 210.

As illustrated in Fig. 6, once the radial expansion of the expandable tubular member 125 has been completed, the tubular support member 105, the tubular expansion cone 110, and the tubular shoe 115 are removed from the wellbore 200. In

particular, the external flange 115c of the tubular shoe 115 engages the internal flange 110d of the tubular expansion cone 110 thereby permitting the tubular shoe to be removed from the wellbore 200.

In a preferred embodiment, the apparatus 100, and method of operating the apparatus, is provided substantially as disclosed in one or more of the following: (1) U.S. patent application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, (2) U.S. patent application serial no. 09/510,913, attorney docket no. 25791.7.02, filed on 2/23/2000, (3) U.S. patent application serial no. 09/502,350, attorney docket no. 25791.8.02, filed on 2/10/2000, (4) U.S. patent application serial no. 09/440,338, attorney docket no. 25791.9.02, filed on 11/15/1999, (5) U.S. patent application serial no. 09/523,460, attorney docket no. 25791.11.02, filed on 3/10/2000, (6) U.S. patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, (7) U.S. patent application serial no. 09/511,941, attorney docket no. 25791.16.02, filed on 2/24/2000, (8) U.S. patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, (9) U.S. patent application serial no. 09/559,122, attorney docket no. 25791.23.02, filed on 4/26/2000, (10) PCT patent application serial no. PCT/US00/18635, attorney docket no. 25791.25.02, filed on 7/9/2000, (11) U.S. provisional patent application serial no. 60/162,671, attorney docket no. 25791.27, filed on 11/1/1999, (12) U.S. provisional patent application serial no. 60/154,047, attorney docket no. 25791.29, filed on 9/16/1999, (13) U.S. provisional patent application serial no. 60/159,082, attorney docket no. 25791.34, filed on 10/12/1999, (14) U.S. provisional patent application serial no. 60/159,039, attorney docket no. 25791.36, filed on 10/12/1999, (15) U.S. provisional patent application serial no. 60/159,033, attorney docket no. 25791.37, filed on 10/12/1999, (16) U.S. provisional patent application serial no. 60/212,359, attorney docket no. 25791.38, filed on 6/19/2000, (17) U.S. provisional patent application serial no. 60/165,228, attorney docket no. 25791.39, filed on 11/12/1999, (18) U.S. provisional patent application serial no. 60/221,443, attorney docket no. 25791.45, filed on 7/28/2000, (19) U.S. provisional patent application serial no. 60/221,645, attorney docket no. 25791.46, filed on 7/28/2000, (20) U.S. provisional patent application serial no. 60/233,638, attorney docket no. 25791.47, filed on 9/18/2000, (21) U.S. provisional patent application serial no. 60/237,334, attorney docket no. 25791.48, filed on 10/2/2000, (22) U.S. provisional patent application serial no. 60/270.007, attorney docket no. 25791.50, filed on 2/20/2001; (23) U.S. provisional patent application serial no. 60/262,434, attorney

docket no. 25791.51, filed on 1/17/2001; (24) U.S. provisional patent application serial no. 60/259,486, attorney docket no. 25791.52, filed on 1/3/2001; and (25) U.S. provisional patent application serial no. 60/303,711, attorney docket no. 25791.44, filed on 7/6/01.

5           It is understood that variations may be made in the foregoing without departing from the scope of the invention. For example, the apparatus 100 may be used to form and/or repair, for example, a wellbore casing, a pipeline, or a structural support. Furthermore, the burst discs 115ea and 115fa may be replaced with conventional pressure relief valves.

10           Although illustrative embodiments of the invention have been shown and described, a wide range of modification, changes and substitution is contemplated in the foregoing disclosure. Accordingly, it is appropriate that the appended claims be construed broadly.

1. A method of coupling a radially expandable tubular member to a preexisting structure, comprising:
- positioning the tubular member within the preexisting structure;
  - injecting fluidic materials into the tubular member;
  - 5 sensing the operating pressure of the fluidic materials;
  - radially expanding and plastically deforming the tubular member into contact with the preexisting structure when the sensed operating pressure exceeds a predetermined amount; and
  - radially expanding and plastically deforming the tubular member using an
  - 10 expansion device when the sensed operating pressure exceeds the predetermined amount.
2. The method of claim 1, wherein the expansion device comprises a tubular expansion cone.
- 15 3. The method of claim 1, wherein sensing the operating pressure includes sensing the operating pressure of the fluidic materials within the tubular member.
- 20 4. The method of claim 1, wherein radially expanding and plastically deforming the tubular member using the expansion device when the sensed operating pressure exceeds the predetermined amount comprises:
- radially expanding and plastically deforming the tubular member by displacing the expansion device in the longitudinal direction relative to the tubular member when the sensed operating pressure exceeds the predetermined amount.
- 25 5. The method of claim 1, further comprising movably coupling a tubular shoe to the expansion device.
6. The method of claim 5, further comprising removing the tubular shoe from the
- 30 preexisting structure.
7. The method of claim 6, further comprising removing the tubular shoe from the preexisting structure by lifting the tubular shoe using the tubular expansion cone.

8. The method of claim 1, further comprising:  
coupling a shoe to an end of the tubular member;  
positioning the expansion device within the tubular member; and  
removing the shoe from the interior of the tubular member using the expansion  
5 device;  
wherein radially expanding and plastically deforming the tubular member using  
the expansion device when the sensed operating pressure exceeds the predetermined  
amount comprises:  
pressurizing an interior portion of the tubular member defined between the shoe  
10 and the expansion device to radially expand and plastically deform the tubular member.
9. The method of claim 1, further comprising:  
coupling a shoe to an end of the tubular member;  
positioning an expansion device within the tubular member; and  
removing the shoe from the interior of the tubular member using the expansion  
15 device.
10. The method of claim 8 or 9, further comprising removing the shoe from the  
interior of the tubular member by lifting the shoe using the expansion device.
- 20 11. The method of any one of the preceding claims, wherein the tubular member  
comprises a wellbore casing, a pipeline, or a structural support.
12. A system for coupling a radially expandable tubular member to a preexisting  
25 structure, comprising:  
means for positioning the tubular member within the preexisting structure;  
means for injecting fluidic materials into the tubular member;  
means for sensing the operating pressure of the fluidic materials;  
means for radially expanding the tubular member into contact with the preexisting  
30 structure when the sensed operating pressure exceeds a predetermined amount; and  
means for radially expanding and plastically deforming the tubular member using  
an expansion device when the sensed operating pressure exceeds the predetermined  
amount.

13. The system of claim 12 further comprising:  
a tubular support member including a first passage;  
wherein the expansion device comprises:  
a tubular expansion cone coupled to the tubular support member defining a  
5 second passage and including an internal flange;  
wherein the means for radially expanding and plastically deforming the tubular  
member using an expansion device when the sensed operating pressure exceeds the  
predetermined amount comprises:  
a tubular shoe movably received within the second passage of the tubular  
10 expansion cone defining one or more radial passages and a valveable passage fluidly  
coupled to the first passage and including an external flange for engaging the internal  
flange; and  
one or more pressure relief valves positioned in corresponding ones of the radial  
passages; and  
15 wherein an expandable tubular member is movably coupled to the tubular  
expansion cone.
14. The system of claim 12 wherein the expansion device comprises a tubular  
expansion cone.
- 20 15. The system of claim 12, wherein the means for sensing the operating pressure  
includes means for sensing the operating pressure of the fluidic materials within the  
tubular member.
- 25 16. The system of claim 12, wherein the means for radially expanding and plastically  
deforming the tubular member using an expansion device when the sensed operating  
pressure exceeds the predetermined amount comprises:  
means for radially expanding and plastically deforming the tubular member by  
displacing the expansion device in the longitudinal direction relative to the tubular  
30 member when the sensed operating pressure exceeds the predetermined amount.
17. The system of claim 12, further comprising:  
a support member to which the expansion device is movably coupled  
wherein the expansion device comprises:

one or more expansion surfaces adapted to be displaced in the longitudinal direction relative to the support member for engaging and radially expanding and plastically deforming the expandable tubular member;

5 wherein the means for radially expanding and plastically deforming the tubular member using the expansion device when the sensed operating pressure exceeds the predetermined amount comprises:

one or more pressure sensing elements coupled to the expansion surfaces; and

10 wherein the one or more pressure sensing elements control the longitudinal displacement of the expansion surfaces as a function of the sensed operating pressure within the expandable tubular member.

18. The system of claim 12, further comprising means for movably coupling a tubular shoe to the expansion device.

15 19. The system of claim 12, further comprising:  
an end of a tapered tubular member coupled to an end of the expandable tubular member;  
an end of another tubular member coupled to another end of the tapered tubular member;

20 a tubular support member;  
wherein the expansion device comprises a tubular expansion cone;  
wherein an end of the tubular expansion cone is coupled to an end of the tubular support member and positioned within the tapered tubular member, wherein another end of the tubular expansion cone comprises an internal flange; and

25 wherein the means for radially expanding and plastically deforming the tubular member using the expansion device when the sensed operating pressure exceeds the predetermined amount comprises:

30 an end of a tubular shoe defining a valveable longitudinal passage and one or more radial passages supported by the end of the other tubular member, wherein another end of the tubular shoe comprises an external flange; and  
one or more burst discs coupled to and positioned within each of the radial passages.

20. The system of claim 12, further comprising:

means for coupling a shoe to an end of the tubular member;  
means for positioning the expansion device within the tubular member; and  
means for removing the shoe from the interior of the tubular member using the  
expansion device;

5 wherein the means for radially expanding and plastically deforming the tubular  
member using the expansion device when the sensed operating pressure exceeds the  
predetermined amount comprises:

means for pressurizing an interior portion of the tubular member defined between  
the shoe and the expansion device to radially expand and plastically deform the tubular  
10 member.

21. The system of claim 12, further comprising:

means for coupling a shoe to an end of the tubular member;

means for positioning the expansion device within the tubular member;

15 and

means for removing the shoe from the interior of the tubular member using the  
expansion device.

22. The system of any one of claims 13, 20 or 21, further comprising:

means for removing the shoe from the interior of the tubular member by lifting the  
shoe using the expansion device.

23. The system of any one of claims 12 to 22, wherein the tubular member comprises  
a wellbore casing, a pipeline, or a structural support.

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